

CENTRAL LIBRARY

Los Angeles, CA

April 29, 1986



FIRE INVESTIGATIONS

NATIONAL FIRE PROTECTION ASSOCIATION

1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101 USA

Telephone: 1-617-984-7263

E-mail: investigations@nfpa.org



"Moving Mankind Toward Safety From Fire"

NATIONAL
FIRE PROTECTION
ASSOCIATION
INTERNATIONAL

Investigation Report

Central Library Fire
Los Angeles, California
April 29, 1986

Prepared By

Michael S. Isner

Fire Protection Specialist

Fire Investigations and Applied Research Division

National Fire Protection Association

ABSTRACT

On April 29, 1986 at approximately 1050 hours a fire occurred in the Central Library of Los Angeles, California. The 400 building occupants evacuated the library in about eight minutes without a mishap. The ensuing fire resulted in a commitment of over 70 pieces of fire apparatus and nearly 350 Los Angeles fire fighters. Despite this commitment, it took fire fighters 7 1/2 hours to extinguish the fire in this partially sprinklered building. Fifty fire fighters were injured during fire suppression; however, none of the injuries were serious. The fire destroyed an estimated 200,000 books, the largest collection of patents in the western United States, and 2/3 of the library's magazine collection. In addition, about half the library's 1.2 million volumes were damaged by water and smoke.

Investigators from the City of Los Angeles Fire Department determined that the area of fire origin was in one of the book stacks and that the fire was suspicious. The first indication of a potential fire came from a smoke detector. Security personnel called the fire department, assisted the library staff with the building evacuation, and helped fire fighters find their way through the building. Once the fire was ignited, openings in the floors between tiers allowed the fire to rapidly spread both vertically and horizontally.

The complex arrangement of the large floors prevented fire fighters from immediately locating the fire and assessing its severity. Once near the point of origin, fire fighters found a hot, rapidly spreading fire in areas to which they had limited access. The lack of sprinkler protection, the presence of vertical ventilation and other unprotected openings in the book stack area, and the abundant fuel in the form of books contributed to the severity of the fire. In addition, the substantial construction and complex design of the building prevented quick extinguishment of the fire.

TABLE OF CONTENTS

	<u>PAGE</u>
I. INTRODUCTION	1
II. BACKGROUND	
- Building History	3
- The Building	4
- Fire Protection in Building	6
- Municipal Fire Protection	8
III. THE INCIDENT	
- Discovery and Initial Fire Department Response	9
- Fire Suppression	10
- Book Salvage Operations	14
- Casualties and Damage	15
IV. ANALYSIS	17
V. DISCUSSION	22
VI. APPENDICES	
- Appendix A: Time Line	25
- Appendix B: List of Damaged Materials	28
- Appendix C: Library Fire Loss Data	29
- Appendix D: Figures	32
- Appendix E: Photographs	40

I. INTRODUCTION

The National Fire Protection Association (NFPA) investigated the Los Angeles Central Library fire in order to document and analyze significant factors that resulted in the loss of property.

This study was funded by the NFPA as part of an on-going program to investigate technically significant fires. The NFPA's Fire Investigations and Applied Research Division documents and analyzes incident details so that it may report lessons learned for life safety and property loss prevention purposes.

The NFPA was assisted in data collection and analysis by International Conference of Building Code Officials (ICBO) under an agreement between NFPA and the three model building code organizations to investigate significant structural fires throughout the United States. In addition to ICBO, the other cooperating building groups are the the Building Officials and Code Administrators International (BOCA) and the Southern Building Code Congress International (SBCCI). The three model building code groups are supporting NFPA by lending technical staff support for on-site field work and building code analysis.

The NFPA became aware of the fire on the day of occurrence, April 29, 1986. Michael S. Isner, Fire Investigations and Applied Research Division, visited the Los Angeles Central Library to document the facts related to the fire. The NFPA investigator was joined and assisted by T. J. Koyamatsu (ICBO), and John Morris (a private consultant). A four-day, on-site study and subsequent analysis were the basis for this report and NFPA's analysis of the event. Entry to the fire scene and data collection activities were made possible through the cooperation of the Los Angeles City Fire Department. This report presents the findings of the NFPA data collection and analysis effort.

This report is another of NFPA's studies of fires having particular educational or technical interest. The information presented is based on the best data available during the on-site data collection phase and during the report development process. It is not NFPA's intention that this report pass judgment on, or fix liability for, the loss of property at the Los Angeles Central Library.

The cooperation and assistance of Fire Chief Manning, Los Angeles City Fire Department; Fire Marshal Craig Drummond, Los Angeles City Fire Department; Battalion Chief Raymond Olsen, Los Angeles City Fire Department; Deputy Chief Donald Anthony, Los Angeles City Fire Department; and others in the Bureau of Fire Prevention, Los Angeles City Fire Department, are acknowledged and appreciated. The author thanks John Morris, Private Consultant for his on-site assistance and his input during analysis of the incident. The assistance of Stephen Bush, Safety Officer, Library of Congress; and Peter Waters, Library of Congress, are also recognized.

Special thanks is given to T.J. Koyamatsu, P.E., Chief Plan Check Engineer, International Conference of Building Officials, for his on-site assistance in the data collection phase and for his input to the code analysis portion of the report.

BACKGROUND

Building History

The Central Library in Los Angeles is the third largest library in the United States. In addition to its collection of 1.2 million books, the facility contains trademark records, patents, magazines, sheet music, maps, and other materials. The nature, quantity, and uniqueness of many materials make this library an extremely valuable resource to researchers.

For years, the Central Library had been recognized as being too small for the collections. To remedy the situation, several plans have been proposed but these have resulted in considerable controversy regarding the future of the building. Some developers proposed the razing of the library to provide space for new construction. Other parties suggested that the building be modified and still others wanted the original structure to be preserved. The complexity of the controversy increased when the library was listed by the city as a historical monument in 1967 and was included in the National Register of Historical Buildings in 1970. Amid the debate regarding the future of the library, the Los Angeles Fire Department continued their efforts to have the library management address conditions within the building that could compromise public safety and enhance fire spread. Many of the items of concern to the fire department had been identified as far back as the 1940s.

In 1981, a plan to upgrade many of the life safety features of the building was approved. So at the time of the fire, smoke detectors had been installed and were operational in the book stack areas. The installation of a 1-hour fire separation at each stairway and each entrance to the book stack area was continuing but not completed.

The Building

The Central Library was constructed in 1926 using the most current technology available. The main structure, which is 240 feet long by 200 feet deep, has three stories plus a basement. In addition a two-story wing measuring 130 feet by 90 feet is attached to the southeast side of the structure (see Photo 1). A tower-like structure extends above the roof of the main structure and covers an open area called the Rotunda. The floor for this area is at the second floor level of the building and measures 40 feet by 40 feet. The ceiling for the Rotunda is 55 feet above the second floor.

Except for the primary book storage areas, the library is considered to be a fire-resistive structure (i.e. Type I - 332).¹ The external bearing walls are reinforced concrete and 16 inches thick. The bearing walls that envelope the Rotunda and support the tower are also reinforced concrete; however, these walls are three feet thick. A network of concrete columns (some as large as three feet by five feet) and beams support the 6-inch roof and floor slabs. Nonbearing walls are constructed with a terra cotta material and mortar. Both the bearing and nonbearing building components are covered with plaster veneer up to 1-inch thick.

The main book storage areas are called the "book stacks" and are closed to the public. Located at the four corners of the Rotunda, these areas are separated from the main structure by the three-foot thick concrete walls and by the terra cotta walls. Originally, nonrated wood doors at each floor level provided access to the stack area; these doors were being replaced with 20-minute rated solid-core wood doors equipped with magnetic door holders.

¹NFPA 220, Standard on Types of Building Construction, 1985 edition. A Type I (332) structure will have a 3-hour fire rating for the exterior bearing walls (first digit), 3-hour fire rating for structural frame or columns and girders, supporting loads for more than one floor (second digit), and 2-hour fire rating for the floor assembly (third digit).

The four stacks are actually voids that resemble large elevator shafts and extend from the basement to the underside of the ceiling/floor assembly between the second and third floors (see Figure 1). The two stacks on the west side of the building are connected and form a single horizontal space at the first and second tier levels in the basement. Similarly, the east stacks are connected and form a horizontal space at the first and second stack levels. The four stacks are separated as they pass through the first and second floors (tier levels 3, 4, 5, & 6). At these levels, the northeast and northwest stacks are rectangular and measure 40 feet by 45 feet. The two southern stacks are basically rectangles measuring 40 feet by 45 feet; however, these stacks are also open to an attached area that is 10 feet by 25 feet. Corridors connect all four stacks at the seventh tier level (see Figures 1 & 2). In addition to seven levels of tiers, there are four rooms (Fiction/Literature Work Room, History Work Room, Map Work Room, and Science and Technology/Patent Work Room) located between the sixth and seventh tier levels; these rooms are considered the 6 1/2 tier and are shown in Figure 2.

Due to their size, each book stack has a central access aisle, which leads to the open stairway within the stack. Rows of bookshelves are perpendicular to and on both sides of this aisle. Smaller aisles that are also perpendicular to the central access aisle run between the rows of bookshelves.

The shelves are supported by steel columns spaced three feet on center along the length of the book shelves and four feet on center between each row of shelves (see Figure 3). The steel columns consisted of two pieces of 1/16-inch thick shaped steel that have been placed together to form a 2-inch square cross section. Each column is supported by a 6-inch square steel plate resting on the concrete slab on grade. The columns are continuous from the first tier in the basement through the seventh tier just below the third floor.

The columns have punch holes along their full length so brackets that support bookshelves may be attached (see Photo 2). Even though the shelf height is adjustable, there are normally seven or eight shelves (3 feet long and 8 inches deep) between columns at all tier levels. Most shelves were filled to capacity so fuel loading in the book stacks is estimated at 93 lbs. per square foot.

Stairways in the stack area are 36 inches wide and have no door protecting the openings at floor levels. These stairways do not have landings between tier levels and are vertically in-line (see Figure 4). A person traveling between tier levels must leave the stairway at any tier and use an aisle to reach the entrance of the stairway to the next tier level.

A mechanical air-handling system enhances the natural air circulation within the stack levels. Makeup air is drawn in at the base of the stacks and is discharged at each tier level. A duct on the opposite side of the tiers collects air from the stack and then the air is discharged at roof level (see Figure 4). Openings between the bookshelves and walkways (opening #1, see Figure 3), between the backs of bookshelves (opening #2, see Figure 3), and around the entire perimeter of the stack area also contribute to air circulation within the book stacks. Apparently, circulating air would contribute to the heating of the stacks and would help preserve books and reduce mildew in the non-air-conditioned building.

Fire Protection in the Building

The building has a wet pipe sprinkler system that only protects the bindery located in the basement. This partial system has a 6-inch feed main and an alarm valve that is interlocked to the building alarm system and with a central alarm service. In addition to the sprinkler system, manual hose stations are provided throughout the basement and at each floor level in the

stairways for the main structure. Portable, pressurized water fire extinguishers are provided for the entire building. The boiler room and work areas in the basement have portable CO₂ and dry chemical extinguishers.

As part of the project to improve fire protection in the building, manual pull stations and smoke detectors have been installed in all the book stacks. The detectors were placed in alternating aisles between the bookshelves, and were spaced 18 feet apart in each aisle. These devices have been connected with the building's local alarm system. In addition, manual stations were provided in the areas normally occupied by patrons. However, these stations initiated a local alarm and notified the central alarm service. Emergency lighting was provided in the stack area and would operate in the event of a power outage.

Upon activation by any means, the alarm system will provide a visual confirmation of the alarm on annunciator panels located in a third floor communications room, in a first floor corridor by the Fifth Street entrance, and in the basement boiler room. Even though the building has 38 zones, the alarm panel on the first floor provides only an indication of the general part of the building where the alarm activated. The other two panels had more complete information regarding the fire zones.

Nearly 200 staff personnel and four security guards are in the building during the day. After the building is closed, only two guards remain.

Both staff personnel and guards have been trained regarding fire emergency and other procedures as contained in the disaster plan for the library. In short the plan indicates that employees and managers are responsible for the safe evacuation of patrons within their respective work areas. The library's head administrator indicated that the staff is well practiced with regard to building evacuation. In addition to the periodic evacuation drills, the library is frequently evacuated because of earthquake alerts.

Municipal Fire Protection

The Los Angeles City Fire Department was incorporated in 1886. This department has the responsibility of protecting a city that covers approximately 470 square miles. To accomplish this task, the L.A. City Fire Department has 1813 full-time paid fire-fighters, 614 officers, 347 emergency medical personnel and a fire prevention bureau of about 130 inspectors and officers. The 100 fire stations and 3 boat houses contain over 205 fire and emergency medical apparatus. The fire station containing Task Force-3 is the closest station to the Los Angeles Central Library only .6 miles away.

THE INCIDENT^{2, 3, 4}

Discovery and Initial Fire Department Response

On the morning of the fire, the Central Library was open for use and was occupied by approximately 200 patrons in addition to the staff that are usually in the facility. Activities appeared to be normal in the building, until the local alarm bells began to operate. Security personnel investigated the situation and the library operator called the fire department to report that bells were ringing (1052 hours). The central alarm service also called the fire department (1055 hours, according to the clock at the central station). Library staff personnel ensured that all patrons in their respective areas evacuated and performed other duties as dictated in the disaster plan. Apparently, the building was completely evacuated in about 8 minutes.

Upon notification of the fire, the Operations Control Division (OCD) dispatched two task forces,⁵ an engine, a squad, and one Battalion Chief (1053 hours). The engine company arrived (1057 hours) and found no visible indication of a fire. The crew entered the building through the Fifth Street entrance and went to the alarm panel on the first floor. Within moments of the first engine's arrival, Engine 3 (from TF-3) arrived and the crew from

²Details in this section and diagrams regarding fire extension have been based upon the Los Angeles City Fire Department report, which was prepared by Deputy Chief Donald Anthony.

³See Appendix I for Time Line.

⁴For more details regarding fire fighting operations, see "Fire Strikes the Los Angeles Central Library", Fire Command, October 1986, Vol. 53, No. 10, pp. 26 - 29, 42 -43.

⁵Note: A Task Force (TF) includes a two-piece engine company, a truck company and 10 fire fighters. A Light Force (LF) includes an engine, a truck, and six fire fighters.

this engine also entered the Fifth Street corridor. They met the crew from the first engine -- Company 10 -- at the alarm panel. Unable to determine the nature of the problem or reset the alarm, one crew went to the alarm panel on the third floor while the other crew (E-3) went to the panel in the basement.

The responding squad and battalion chief arrived at the Fifth Street side of the library about the same time as E-3. There still was no visual indication of the fire from their vantage point. The second arriving Task Force responded to the Hope Street side of the building and one of the engine companies noted that light smoke was showing from the east side of the building at roof level. The battalion chief requested assistance and OCD dispatched four more Task Forces, a Light Force, and two engine companies.

When the E-10 crew arrived on the third floor, they found light smoke in a corridor and heavy smoke in a room. This crew requested assistance (1114 hours) and deteriorating conditions eventually forced them from the area. The E-10 crew exited the third floor by a fire escape ladder at a window. The ladder allowed the crew to move to the roof of the east wing where they requested 1 1/2 hoses and other equipment. With this equipment, the fire fighters reentered the building at the Fiction and Literature Workroom (6 1/2 tier level) and went up a ramp to enter the 7th tier of the NE stack (see Figures 2 & 4).

Fire Suppression

Having identified the location of the detector activations from the main alarm panel, the E-3 crew entered the NE stack in the basement and climbed the 36-inch wide open stairs to the 5th tier where they left the stack to tie into a hose station located in a stairway leading to the second floor (see Figure 4). The crew reentered the stack at the 5th tier level, advanced their hose

lines through the maze of bookshelves and winding stairs in order to attack the fire on the 6th tier.

The E-10 crew was joined by the crew from LF-11 which also entered the building from roof of east wing. Several crews that entered the NE stack from the second floor began to assist in the attack of the fire in the NE stack. Another crew entered the southeast stack from the second floor, advanced their line to the 7th tier, and began to attack the fire from the south side.

By 1130 hours, 22 fire companies, eight command and staff officers and a rescue ambulance had been committed to the fire. Fire officers began to recognize many of the problems that would plague them throughout the fire. Access to the fire area was limited to the small 36-inch stairways in the stacks and the ramp from the Fiction and Literature Workroom. The lack of ventilation permitted both smoke and heat to accumulate making fire fighting difficult and conditions unbearable.

Between 1130 hours and 1200 hours, the fire appeared to be limited to the northeast stack even though fire fighters were unable to advance hose lines within the stack levels. Outside of the building, arriving officers were assigned various responsibilities and the commitment of additional fire companies was continuing. Some fire fighters started salvage operations on the first floor, second floor, and the lower tiers in the northeast stack. Bookshelves and furniture were covered with polyethylene plastic or salvage covers and dikes were made with sawdust to direct water out of the building. Other arriving fire fighters were assigned to assist the attack crews, which were being rotated every 15-20 minutes because the heat in the area of attack was so great.

By 1200 hours, the incident command post and medical area were established on Fifth Street. A unit for resupplying air was requested and the fire

department's Supply and Maintenance Division had been notified. There were now 24 fire companies, 10 command and staff officers, and 5 rescue ambulances assigned to the emergency.

Shortly after 1200 hours, an officer reported fire inside a third floor wall, located in the northwest corner of the building. The lack of ventilation continued to make conditions worse in the area of the fire attack and 2 1/2-inch hoses were being fed through the bookshelves and winding stairways to be used as attack lines. Despite the use of 1 1/2-inch handlines to keep attack crews cool, the fire fighters with the 2 1/2-inch hose were still unable to advance. Occasionally, when attack teams open their nozzles, they were driven back by steam.

At 1225 hours, fire fighters discovered that fire had progressed from the northeast stack to the northwest stack through a corridor that connected the two areas. The fire attack teams that were assigned to the northwest stack found that the fire had begun to spread down and involved both the 6th and 7th tiers. They also experienced the extreme heat that plagued fire fighters in the northeast stack. Ventilation attempts using sledge hammers and axes did not produce holes large enough to be effective.

By 1300 hours, the fire department commitment increased to 34 companies, 12 officers, 1 helicopter, and 7 rescue ambulances. It was about this time that fire became visible in the Patent Room (6 1/2 tier). Recognizing the potential for structural collapse in the book stack areas, it was decided that a rescue team would be kept on standby so they could immediately respond if necessary. A heavy utility vehicle was requested because it contained pneumatic hammers that could be used to cut ventilation holes.

At approximately 1330 hours, the majority of fire in the northeast stack had been knocked down. The corridor was still too hot to enter; temperatures were estimated at 2000 - 2400°F. As in the corridor, extreme temperatures

in the northwest stack and Patent Room prevented entry. As a result, two ladder pipes were positioned outside the Patent Room. When the attack crews were removed from the area, the exterior heavy streams were directed into the Patent Room for two minutes. Fire and high temperatures in the Patent Room still prevented fire fighters from entering the room so the appliances were operated again for six minutes. It was about this time that the 7th tier in the northwest stack collapsed.

The interior attack was renewed by 1400 hours. Some fire fighters entered the Patent Room to extinguish the remaining fire. Other fire fighters with 2 1/2-inch and 1 1/2-inch hoses entered the stack areas from the Patent Room, from the southwest side of the 7th tier, and up the stairs in the northwest stack. Progress in the stacks was extremely slow because of high heat and limited access to the northwest stacks.

By 1500 hours, the spread of fire to uninvolved areas was apparently stopped but the fire fighters still could not enter the northwest stack or the corridor. The heat absorbed by the concrete walls kept many areas unbearably hot even though the fire had been knocked down. Fire fighters equipped with pneumatic hammers began to cut holes in the third floor slab to ventilate the 7th tier. Even though fans were used to ventilate the work areas, the fire fighters operating the jackhammers had to be cooled with water spray from 1 1/2-inch hoses and many fire fighters stood in water that was boiling because the slab was so hot. Once some of the holes were made (1530 hours), distributor nozzles were placed into areas where fire fighters could not gain access. It was about this time that a large hole was cut into a wall in the Patent Room and provided additional access to the northwest stack at the 7th tier level.

The improved ventilation dramatically affected the fire fighting efforts and attack teams began to make progress. By 1700 hours, fire in the northeast

stack, the Patent Room, and two rooms on the third floor had been controlled; however, the fire in the northwest stack was still burning. The fire in the Central Library was declared extinguished at 1830 hours. Fire fighters, however, remained on the scene to guard against hotspots and rekindle.

The 7 1/2-hour fire resulted in the commitment of 45 percent of the Los Angeles City Fire Department resources. This included:

- 60 fire companies (Engines and Trucks)
- 1 arson unit
- 9 paramedic rescue ambulances
- 3 helicopters
- 4 salvage companies
- 1 squad
- 2 emergency air units -- units on scene for several days
- 1 heavy utility company
- 350 fire personnel (including 40 staff and support personnel)

In addition to the units from the LA City Fire Department, six mutual aid units from LA county, five private ambulances, and a hospital emergency response team from USC responded during this incident.

Book Salvage Operations*

Fire fighting crews began to protect books early in the fire and used nearly 100 rolls of polyethylene in addition to their normal salvage covers. As soon as allowed, staff personnel entered and began to formulate their plan for salvaging books. It was important to quickly remove the books, especially the wet and damp ones, because mildew can begin to grow in about 48 hours and it can be as damaging to books as flames or smoke. Eventually, crews of city employees and others were brought in to assist in the removal of water and the stabilizing of conditions.

A consultant was retained to organize the book removal operation such as proper packaging of books, identification and recording of books as they are

*For information regarding the salvage of water-damaged library materials, see Emergency Procedures for Salvaging Flood or Water-damaged Materials, Peter Waters, 1972, Library of Congress, Washington D.C.

packaged, and training personnel with regard to proper work procedures. In addition to organizing these activities, the contractor needed to secure several lift trucks to move the pallets of books, many tractor-trailer trucks to carry the books to the storage areas (see Photo 3), and large freezers for the estimated 1600 pallet loads of wet books. He also made arrangements with a local Convention Center for temporary storage of the estimated 650 pallets containing dry books.

Since an immense amount of books needed to be removed from the building, it was decided that a call for volunteers would be made to the community. In response, relatives of staff personnel, people from the city of Los Angeles and adjacent communities, youth groups like the California Conservation Corps, and many other people came to the Central Library to help. An estimated 1500 people volunteered and assisted during the four-day, 24-hour, book-moving operation. Besides training and managing these people, the library administrators had to ensure that their sanitation, nutrition, and medical needs were met.

Casualties and Damage

During this fire, 50 fire fighters were treated for burns or heat-related injuries. Of these people, 28 were transported to the hospital and all but eight were released the same day. In addition to the fire fighters that were injured, one civilian received a minor ankle injury.

On the 5th tier of the northeast stack, the fire spread along the shelves on both sides of the aisle in which the fire started. The fire extended about 10 feet horizontally in both directions from the suspected point(s) of fire origin. The fire spread into adjacent aisles and up into the tier level above (see Figure 5). Only a small percentage of books were involved on the 5th tier level. Once in the 6th tier, nearly one-third of the books were burned and the others received some smoke and heat damage.

The fire spread up into the tier above. Except for the books in the corner near the stairway (see Figure 6), materials in the 7th tier area directly above the northeast stack were severely damaged by flames or heat. Approximately four rows of bookshelves in this part of the 7th tier collapsed and fell into the 6th tier. The collapse extended only about half the length of the northeast stack.

The fire consumed most material in a dead-end corridor near the northeast stack (see Figure 6). A concrete beam near this corridor had some spalling damage. Only traces remained of the combustible materials that were in the corridor between the northeast and northwest stacks. The 1-inch plaster veneer fell off all surfaces in this corridor and several beams at the west end were severely spalled; a crack in one beam resulted in that member separating from the ceiling/floor slab above. The fire also consumed most combustible materials in the dead-end corridor that was adjacent to the northwest stack (see Figure 6). Once in the northwest stack, the fire caused severe damage and resulted in the collapse of four more rows of bookshelves. This area of collapse, however, extended the full length of the northwest stack (see Photo 4).

The fire involved 7th tier books as far as the southwest stack. The remaining areas of the 7th tier had varying degrees of smoke and heat damage (see Figure 6). Several rooms on the 6 1/2 tier level were damaged by smoke and fire. The Patent Room was gutted (see Photo 5); the Map Room was severely damaged by smoke, and remaining rooms on the 6 1/2 tier received some smoke damage.

Two rooms on the third floor were severely damaged by fire and all other areas had varying amounts of smoke damage. Fire fighters cut 18 holes into the 3rd floor slab to ventilate the 7th tier (see Photos 6 & 7).

An estimated 3 million gallons of water was used during the 7 1/2 hours of fire fighting. Run-off water from fire fighting operations was evident in most areas of the building including the basement where water nearly 50 inches deep accumulated in the boiler room. Even though water penetrated most areas in the building, the most severe water damage occurred on the west side of the building. This was the side where the most severe fire damage occurred and where the heavy stream appliances were used.

Of the 1.2 million volumes, an estimated 200,000 volumes were destroyed by fire. Another 150,000 volumes were damaged by fire or smoke but were dry and appeared salvageable. In addition to this material, 600,000 volumes were wet and in frozen storage pending evaluation. One of the most devastating losses to the library was the loss of its patent collection which contained U.S. patents dating back to 1790, irreplaceable patents from USSR, Germany, and Cuba, and replaceable patents from other countries. (See Appendix B for a more complete list of losses.) The dollar loss value has been estimated at \$22 million for building contents and \$2 million damage to the building.

ANALYSIS

City of Los Angeles Fire Investigators have determined that the fire was of a suspicious nature. It appears that fires were intentionally set in the third or fourth shelves on each side of a fifth tier aisle in the northeast stack. No evidence of accelerant was found near the suspected area of fire origin.

Once ignited, the fire burned deeply into the books at and above the area of origin. Beyond this, surface burning occurred along the top and exposed face of the bound magazines and resulted in horizontal fire spread. It appears that the arrangement of the shelves interrupted the natural vertical spread of the flames. As a result, the fire extended further along the top of the books at each shelf level than it did along the exposed faces of the books.

The openings that were provided for air circulation in the stacks, such as those between the walkways and the bookshelves, allowed fire to rapidly spread to tiers above the area of fire origin. The potential for vertical fire spread by this means is well recognized and is the concern of many who wish to prevent fire losses in libraries.^{6,7}

Figure 7 also reveals that a 2-inch space is present between the backs of the bookshelves (opening #2). Like the steel columns, this space is continuous from the basement to the bottom of the third floor slab. The large horizontal opening between shelves at the tier division will allow flames to gain access to the 2-inch vertical opening between shelves. Once in this space, the flames will spread vertically from tier to tier. Since the space is small, radiative feedback between burning surfaces may enhance the fire growth in the space even more.

In addition to the enhanced vertical fire spread, it appears that the shelf arrangement also increased the horizontal fire spread as the fire passed from one tier to the one above. On the 5th tier (NE stack), the fire was relatively minor and involved only a small percentage of the books at that level. The fire involved about one-third of the books on the 6th tier; however, on the 7th tier level the fire involved the majority of the books. This increase of burn area among upper tiers appears to exceed the typical horizontal spread along an uninterrupted and combustible vertical surface.

As indicated earlier, fire on the 5th tier traveled along the bottom of shelves that expanded the horizontal area of involvement between shelves. This phenomena may also explain the notable horizontal spread that occurred

⁶Stephen Bush, "Library and Museum Collections", NFPA Handbook, 16th edition, 1986, pp 11-85.

⁷NFPA 910 Recommend Practice for the Protection of Libraries and Library Collections.

between tiers. A 2- to 3-inch space was present between the upper-most books on one tier and the bottom shelf of the tier above (see Insert, Figure 7). The space is a relatively large uninterrupted channel, which flames may have followed horizontally.

In 1959, Factory Mutual (FM) conducted two test burns that involved a four-tier array of bookshelves.⁸ In one test sprinklers were used and successfully protected the array. In the second test the sprinklers were not used. The fire spread through the array reaching the 4th tier in 9 1/2 minutes. Similar to the fire at the Central Library, flames began to spread across the aisle as the fire penetrated the tiers above the area of fire origin. These findings suggest that both vertical and horizontal fire spread can be enhanced as fire travels between tiers.

On June 29, 1960, Cornell University also performed a test burn at the Ithaca Fire Department Fire Training Building.⁹ In this fire, the array was only one tier high and placed in a small noncombustible room. Filmed documentation of the test revealed that fire quickly spread to the top of the array. The fire primarily involved books within the aisle of fire origin and horizontal fire spread was limited even after 20 minutes of uninterrupted burning. This suggests that the notable horizontal fire spread occurs as fire passes between tiers.

The fire growth rate in the Central Library incident was consistent with the fire growth noted during the FM test burn of the unsprinklered multitier bookstack (see Footnote 8). At the time of fire department arrival (1057 hours), the fire had been burning for at least five minutes and involved the

⁸Factory Mutual Engineering Division, Laboratory Report, December 21, 1959.

⁹H. B. Schell, "Cornell Starts a Fire", Library Journal, Vol. 85, No. 17, October 1, 1960: 3398-9.

5th, 6th, and 7th tiers of the northeast stack. In the FM test, the fire that was started on the 1st tier heavily involved materials on the 3rd tier in about seven minutes.

The multitier fire in the stack area would have been producing large quantities of smoke and heat; however, the first units to arrive on the north side of the building (Fifth Street) saw no smoke. It was not until fire fighters arrived on the south side (Hope Street) that any smoke was observed and this was only light smoke. The lack of externally visible smoke suggests that the smoke and heat were not escaping and were being retained on the 7th tier. Thus, conditions within the space would have quickly deteriorated.

There was no water supply in the stack areas; therefore, fire fighters obtained water from hose stations in the main structure and from supply lines that were brought into the building. Once in the stack, fire fighters advanced the lines through the stairways and aisles until they reached the position for attack. This was a slow and difficult task. The narrow aisles and stairways limited the space available to the fire fighters and their equipment. Once the first attack crews were in position at the top of the stairways and the ramp, trapped heat, gases, and flames prevented them from advancing lines and attacking the deep-seated heavy fire. The areas of decreased fire damage on the 7th tier (see Figure 6) were directly attributed to the fire fighters' ability to keep the fire from spreading to these areas despite immense flames and intense heat.

Because the first attack crews were not able to gain access to the entire perimeter of the fire area from their position at the stairway, the fire was able to continue to spread in areas beyond, such as the corridor between the northeast and northwest stacks. Hot gases preheated the combustible materials stored in the corridor. Once the materials were ignited, fire spread through this corridor rapidly. Some of the most intense burning occurred in this

corridor, as evidenced by the damage to plaster on the walls and by the amount of spalling, especially at the west end of the corridor. Observations by fire fighters confirm that the fire was most intense at the west end of the corridor. It appears that the superheated unburned gas from the northeast stack would ignite as it became exposed to the air in the corridor.

The fire quickly spread through the 7th tier of the northwest stack. Before the fire fighters could prepare an adequate attack, the fire reached the Patent Room through the doorless opening by the ramp. In addition, burning materials that fell through the openings next to the 7th tier book shelves caused fires in the 6th and 5th tiers of the northwest stack. Crews positioned by the stairways in the southwest and southeast stacks were able to prevent fire spread to the south side of the 7th tier and to other areas.

In addition to the problems resulting from limited access points to the fire area and from the maze created by bookshelves and winding stairways, fire fighters were confronted with the building's ability to retain and then later release heat. Early in the fire the massive concrete walls and structural members acted as a heat sink, absorbing immense amounts of heat. As attack crews attempted to extinguish the fire in areas where the intense fire had burned uncontrolled for several hours, (i.e. the corridor between the northeast and northwest stacks), heat from the walls helped to perpetuate the existing fire and decrease the efficiency of extinguishing efforts.

It was not until effective ventilation was provided through the 18 holes in the slab for the third floor that fire fighters began to make progress. With the hot gases and smoke being removed, and nozzles being introduced directly into the superheated space, attack crews were able to make entry into the areas where the deep-seated fire was located. The increased accessibility to the fire area allowed fire fighters to extinguish the remaining fire in about 2 1/2 hours.

Even though damage was estimated at \$22 million and nearly three fourths of the books were affected by fire, smoke, or water, losses in this incident could have conceivably been worse. Fire fighters would have found a more serious fire involving even more of the northeast stack had the fire started on any of the lower tiers in the stack. The Los Angeles City Fire Department had the manpower, skills, and equipment necessary to make the aggressive interior attack using with 2 1/2- and 1 1/2-inch handlines. Their attack was effective despite accessibility problems and extreme conditions. Undoubtedly, the combined efforts of the attack crews and the salvage crews reduced the amount of damage that could have occurred.

Discussion¹⁰

Because of high fuel loads and high value collections, or both, libraries should be considered specialized storage facilities with particular fire protection requirements. There is a tendency to underestimate the fire potential in these facilities because of the low fuel loads normally housed in public areas such as reading rooms. Despite this apparent low fuel load, many library reading rooms have suffered costly losses. Libraries also have nonpublic areas, such as bookstacks, storage rooms, and work rooms that present even greater fire hazards. Here the fuel loads are much higher, and housekeeping and smoking are less likely to be controlled.

The absence of automatic suppression systems that can prevent small fires from becoming larger, is a common condition in libraries that have experienced fire losses (see Appendix C). Traditionally, librarians have felt that water is a greater hazard to their collections than fire. As a result, they have placed emphasis upon fire prevention almost exclusively and, with few

¹⁰Stephen Bush, "Library and Museum Collections", NFPA Handbook, 16th edition, 1986, pg 11-85.

notable exceptions, limit fire protection to the installation of early warning detection systems.

Fire fighters may have to use an immense amount of water during their operations. For example, an estimated 3,000,000 gallons of water was used to extinguish the fire at the Central Library. Their average application rate was 6,670 gpm over the 7 1/2-hour incident. Comparing this rate to the 20-25 gpm application rate from an average sprinkler, one realizes that the operation of few sprinklers early in a fire will minimize the amount of water damage during an actual fire. In addition, sprinklers will extinguish a fire before flames can severely damage books.

Effective fire prevention programs can contribute to the reduction of losses in libraries. Basically, fire prevention consists of controlling ignition sources and the supply of fuel. Some typical ignition sources that may need to be controlled in libraries are smoking, electrical appliances, electrical wiring, electric lights, open flame devices, and heating equipment. While attempting to control fuel, one must consider all combustible contents, including collections and ancillary records as well as furniture, interior finish, packaging materials, and flammable liquids.

Effective fire prevention cannot, however, completely eliminate the potential for library fires. During 1980-1984, fires in library buildings due to incendiary or suspicious causes accounted for an average of 134 fire incidents per year reported to fire departments with an associated average of \$3.5 million per year in direct damage.¹¹ This represented 50 percent of

¹¹These estimates are based on data reported to the annual NFPA survey of fire departments and fire incident reports to the National Fire Incident Reporting System of the U.S. Fire Administration (USFA) combined, using statistical methods developed by analysts at the NFPA, the USFA, and the U.S. Consumer Product Safety Commission. The figures include a proportional share of fires with the ignition factors unreported, and the damage figures may be overly influenced by a simple large fire in 1982.

all structure fires in libraries during this period and 87 percent of all property damage in those fires.

The fire in the Central Library serves as a vivid reminder that serious fires do occur in libraries. To prevent such losses, adequate fire protection provisions must be in place before a fire occurs. Typically, the fire protection provisions will include one, some, or all of the following components:

- Fire-resistive building construction.
- Compartmentalization.
- Detection and early warning.
- Manual suppression.
- Automatic suppression.
- Training.
- Fire prevention.

These and other fire protection measures are discussed in depth in NFPA 910, Recommended Practice for the Protection of Libraries and Library Collections.

NOTE:

On September 3, 1986, the L.A. Central Library was struck by a second fire. Once again, the fire was intentionally ignited and suspicious. This fire occurred shortly after 6 p.m. in the Art and Music area of the library; an area not greatly affected by the first fire. Fire fighters responded with approximately 25 apparatus and extinguished the fire in 30 minutes. The property damage has been estimated at 2 million dollars.

Appendix A
Time Line*

- Building open for normal business and activities -- 200 patrons and 200 employees in building.
- Smoke detectors in NE stack sense smoke and initiate alarm. Order of smoke detectors in NE stack -- 6, 5, 7th tiers.
- Security and staff personnel evacuate building in about 8 minutes.
- 1052 Telephone operator in library calls FD. Indicates "bells were ringing."
- 1053 TF-3, TF-9, E-10, SQ-4 & Battalion 1 arrive.
- 1057 Crew from E-10 arrives at the Fifth Street entrance to the library -- nothing showing.
E-3, SQ-4, and BC-1 arrive at same time -- nothing showing.
Crews from E-10 enter building followed by crew from E-3.
TF-9 arrives at Hope Street and E-9 reports light smoke from the east end of roof.
E-10 on third floor finds light smoke in the corridor and heavy smoke in room on third floor (northeast corner).
E-3 crew investigates and goes to basement to check main alarm panel.
- 1111 BC requests additional help; four TF, two E, and one LF respond.
- 1114 E-10 crew backs out third floor window and move to roof of east side. Crew reenters building at 6 1/2 tier level (Fiction and Literature Workshop) and go up ramp to fire in the 7th tier NE stack.
E-9 enters building from Hope Street entrance.
Security brings them to 5th tier NE stack and they find fire.
E-3 takes NE stack stair from basement to 2nd floor -- leaves stack, gets water and hose and reenters stack.
Other crews arrive and assist in the attack on NE stack.
LF-10 brings hose lines to 7th tier through the southeast stack.
Exterior size-up shows N, S, W sides of the building still clear of smoke; smoke showing on east side.

*Times have been provided by the L.A. City Fire Department.

Time Line Cont'd

1120 Three fully-staffed salvage companies requested.

1127 Heat in northeast stack extreme; attack crews in both the 6th and 7th tiers cannot advance lines any further; cannot ventilate; line advancing is extremely slow because of stair configuration. The impact of these problems are being recognized by fire crews and officers.

1130 22 companies, 8 command staff officers and 1 rescue ambulance arrive at fire.
It appears the fire is contained to NE stack and involves the 6th and 7th tier in the stack.

1130-1200 Salvage operations started.

1156 Ventilation and electrical systems shut down.

1201 Chief Mello reports there is fire in walls of 3rd floor.
Chief Creasy, who is in charge of fire attack, indicates that crews are experiencing serious banking down problem with heat and smoke; crews rotated in 15/20 minute intervals. Crews get superheated steam when lines are opened.

1230 Fire in NE stack and corridor and NW stack.

1230-1300 Fire attack teams directed to NW stack to attack fire from below. These teams also experience high heat, heavy smoke, narrow aisles, and limited access. Attack made with 2 1/2- and 1 1/2-inch hose used to protect fire fighters. Teams rotated every 10 to 15 minutes. Book shelves are cherry red.

1300-1330 Fire visible from windows to patent room.
Fire extends about 300 feet within the 7th tier. Recognition that ventilation is desperately needed and that jackhammers will be required - equipment is requested.
Fire in NE stack is being controlled but fire in corridor between NE and NW stacks still out of control and too hot to enter.
Plan for large stream attack is made.

1344 Personnel removed from NW stack before the use of heavy streams.
Portable monitor nozzle placed in corridor at NE stack end; hall still too hot to enter even with monitor and hand lines.

Time Line Cont'd

1344 (cont'd) Engine battery and ladder pipe apply water to Patent Room; 2 minute application; fire fighters still cannot enter, therefore, both appliances used again for 6 minutes.

1400-1430 Interior attack resumed through Patent Room, from southwest stack towards the northwest stack, and upstairs to northwest stack.
Connecting hall still too hot for entry.
Crews still being rotated.
Fire that spread to southwest stack stopped. Forward movement into NW stack still slow.

1500 All fire spread has been stopped.

1500-1530 Jackhammers brought to 3rd floor and holes are to be cut into floor slab. Jackhammer crews require full protective gear; standing in boiling water; hose lines used to protect jackhammer crews.

1530-1600 Distributors (cellar nozzles) placed into some ventilation holes. Crews cut 18 large holes from Patent Room into the area of the 7th tier of the NW stack.
The major collapse of 6th and 7th tier has occurred. Ventilation begins to help.

1600 The only uncontrolled fire remains deep in the NW stack.

1630-1700 Fire still in NW stack; progress is slow.
Fire is contained in all levels of NW stack, Patent Room, connecting hallway, and two small offices on 3rd floor.

1700-1730 NW stack only area with uncontrolled fire.

1830 Fire is declared out.

Appendix B
List of Damaged Materials

- 1) 85% of the material pertaining to the following topics was totally destroyed:

- Math
- Computer Programming
- Physical Sciences, i.e.
 - Sound
 - Electricity
 - Nuclear Physics
 - General Chemistry
 - Earth Science
- Paleontology
- Anthropology
- Biology
- Zoology

Note: The surviving 15% of the material was in the reading room and not in the stack at the time of the fire.

- 2) Complete loss of uncategorized scientific information, i.e. U.S. Documents (500 series). These were unbound manuscripts.

- 3) Patent Room losses:

- Entire collection:
 - U.S. Patents: 1790 - Current.
 - Canadian Patents: 1890 - Present.
- Partial loss of collection:
 - Great Britain Patents 1855 - Present.
 - Germany 1880 - 1940.
 - USSR 1862 - 1978.
 - Cuba 1915 - 1971.
 - U.S. Trademark 1870 - Present.
 - U.S. Copyright Information.

Note:

- Only complete collection of patents in the western U.S.
- Microfilm copies of patents were in the Patent Room.
- Paper copies of patents in NE and NW stacks.
- Replacement:
 - U.S. Patents easy to replace; will cost about \$250,000.
 - Great Britain and Canadian patents may be replaceable.
 - USSR, Germany, and Cuba may NOT be replaceable.

- 4) Other losses:

Magazines:

- collection of 6,000 titles lost in NE stack.
- examples: Fortune, Time, Life, Trade Magazines, Social Sciences, Art, and Music.
- 2/3 of magazine collection lost, many magazines go back to 1700's.

Fiction collection

- Authors A-G.
- hard-bound text.

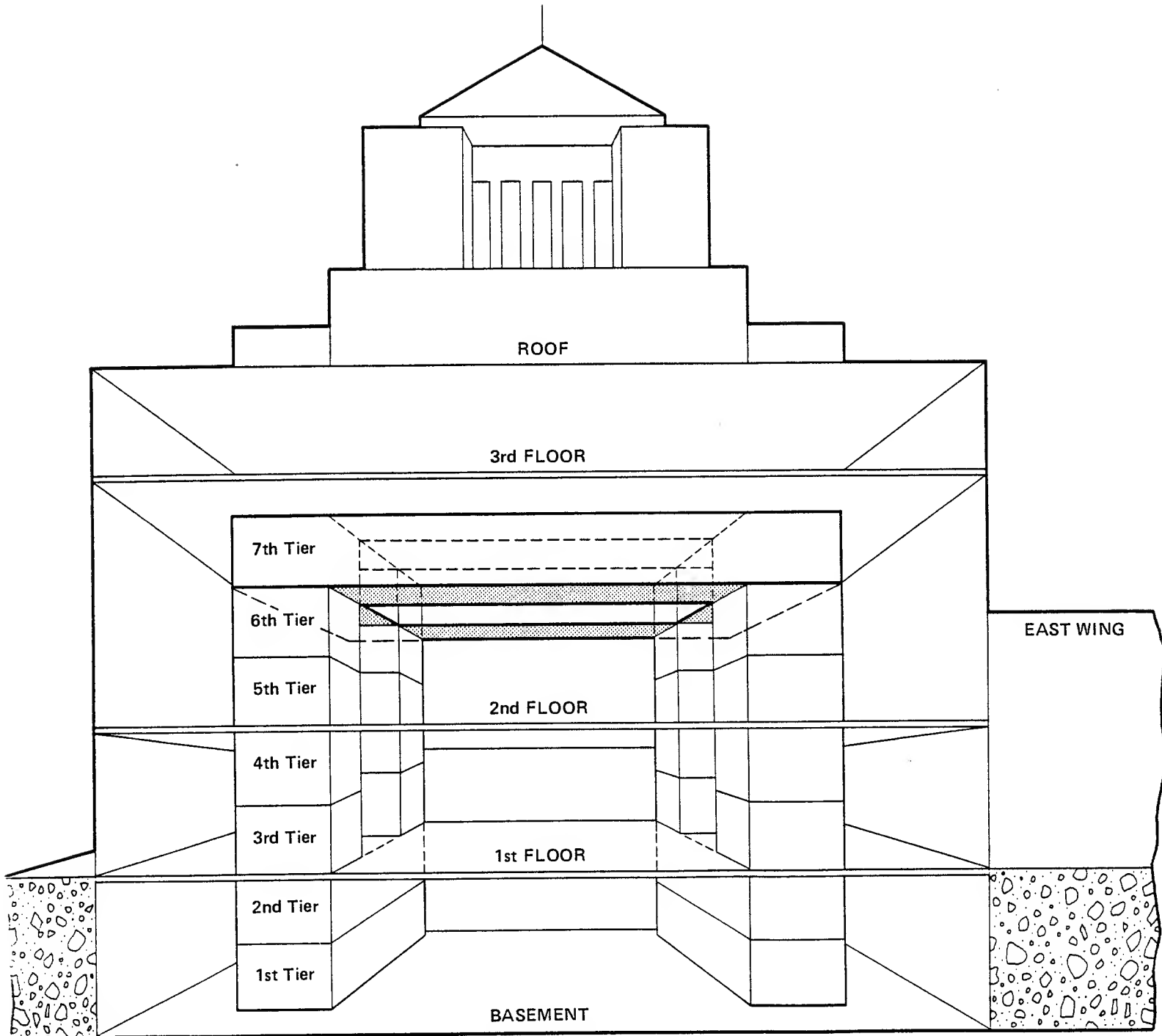
APPENDIX C. LIBRARY FIRE LOSS DATA (FIDO SYSTEM)

<u>DATE AND LOCATION</u>	<u>CAUSE</u>	<u>SPRINKLERS</u>		<u>DETECTORS</u>		<u>DOLLAR LOSS</u>		<u>TOTAL</u>
		<u>INSTALLED</u>	<u>OPERATED</u>	<u>INSTALLED</u>	<u>OPERATED</u>	<u>STRUCTURE</u>	<u>CONTENTS</u>	
11/13/71 Fremont, CA	Design/Constr. Deficiency Unclass	No		No		\$ 35,000	\$ 85,000	\$ 120,000
01/24/72 Los Angeles, CA	Incendiary - Unknown Motive	No		No		2,000	5,000	7,000
12/05/72 Fort Benjamin Harrison, IN	Short Circuit/ Ground Fault	No		No		92,000	158,000	250,000
07/25/72 Philadelphia, PA	Mechanical Fail/ Malfunction Unclass	No		No		---	2,500,000	2,500,000
01/13/74 Grafton, MA	Suspicious	No		No		150,000	45,000	195,000
01/14/74 Seattle, WA	Incendiary - Motive Unknown	No		No		2,000	2,000	4,000
12/01/75 Toledo, OH	Operational Deficiency Unclass	No		No		250,000	300,000	550,000
02/06/75 Weymouth, MA	Incendiary - Motive Unknown	No		Yes	Yes	24,000	35,000	59,000
10/21/75 #4809 North Hampton, MA	Suspicious	Yes	No	Yes	Yes		140,000	140,000

DATE AND LOCATION	CAUSE	SPRINKLERS		DETECTORS		DOLLAR LOSS		TOTAL
		INSTALLED	OPERATED	INSTALLED	OPERATED	STRUCTURE	CONTENTS	
05/14/76 Peabody, MA	Suspicious	No		Yes	Yes	\$1,000,000	---	\$1,000,000
03/31/76 Walker, MN	Unclassified	No		No		\$250,000		250,000
10/10/76 Citrus Heights, CA	Incendiary - Motive Unknown	No		No		---	1,300,000	1,300,000
06/05/77 Oxnard, CA	Short Circuit Ground Fault	No		No		185,000	65,000	250,000
05/23/78 Rochester, NY	Incendiary - To cover crime	No		No		---	---	---
03/04/74 Pleasant Hill, CA	Incendiary - Motive Unknown	No		No		150,000	75,000	225,000
01/12/80 Lake Mills, WI	Short Circuit Ground Fault	No		No		215,000	83,000	298,000
06/21/80 Conroe, TX	Incendiary - To cover crime	No		No		167,000	260,000	427,000
10/08/80 El Cajon, CA	Incendiary - Motive Unknown	No		No		580,000	20,000	600,000

DATE AND LOCATION	CAUSE	SPRINKLERS		DETECTORS		DOLLAR LOSS		TOTAL
		INSTALLED	OPERATED	INSTALLED	OPERATED	STRUCTURE	CONTENTS	
08/15/80 Camden, NJ	Incendiary - Motive Unknown	No		No		\$ ---	\$ ---	\$ ---
02/23/81 #1151 Stillwater, OK	Short Circuit/ Ground Fault	No		Yes	Yes	3,000	---	3,000
01/14/81 Rockville, MD	Incendiary - Motive Unknown	No		No		200,000	300,000	500,000
12/17/81 Salt Lake City, UT	Other Elect. Failure	No		Yes	Yes	---	---	8,000
04/13/82 #447 Los Angeles, CA	Incendiary - Motive Unknown	No		No		1,000,000	3,000,000	4,000,000
06/07/82 Newton, MA	Incendiary - Motive Unknown	No		No				150,000
07/31/82 #2046 St. Joseph, MO	Incendiary - For Personal Kicks	Yes	Yes	Yes	Yes			

APPENDIX D
FIGURES



The Los Angeles Central Library SIMPLIFIED DIAGRAM

Figure 1

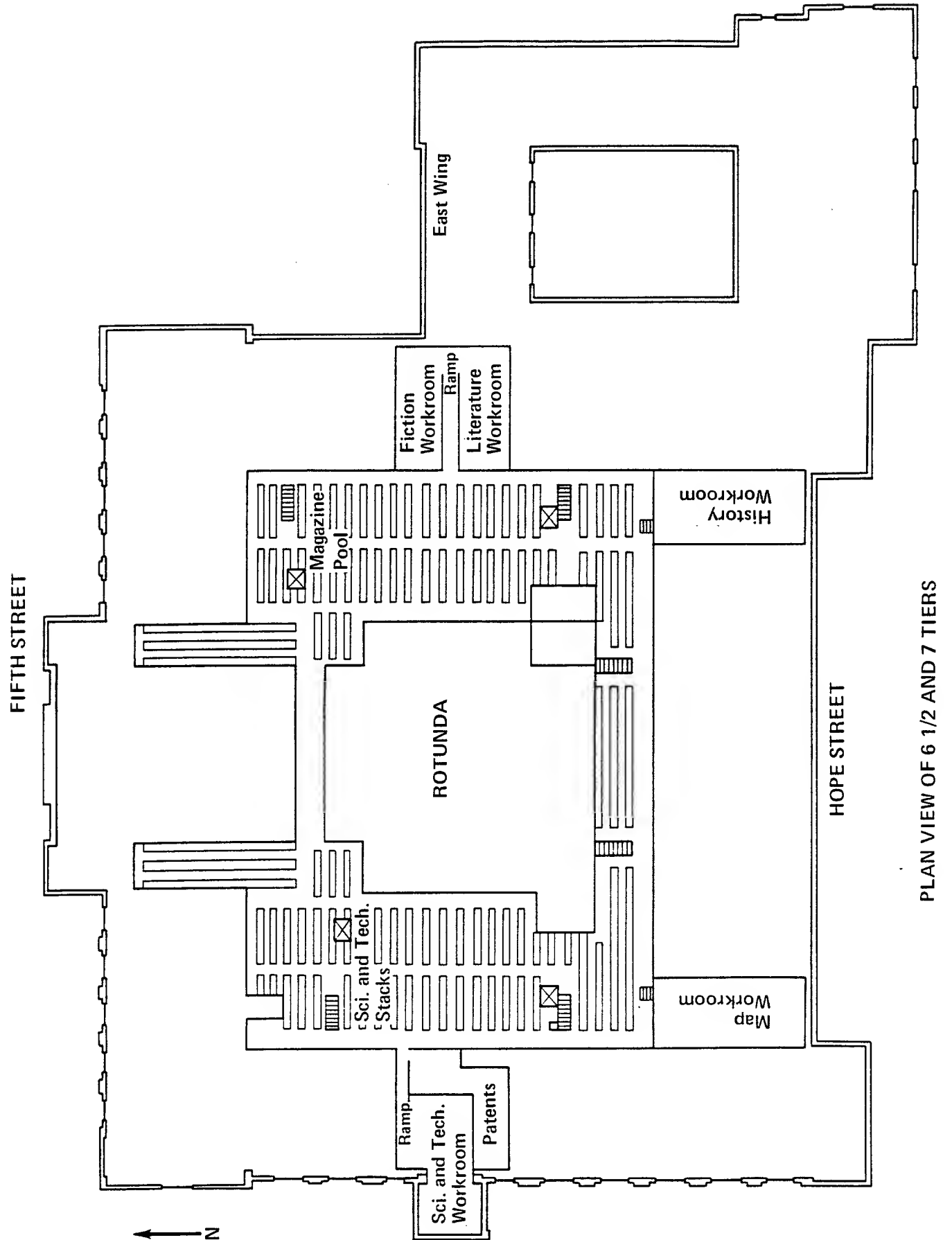


Figure 2

Typical Shelf Arrangement (Not to Scale)

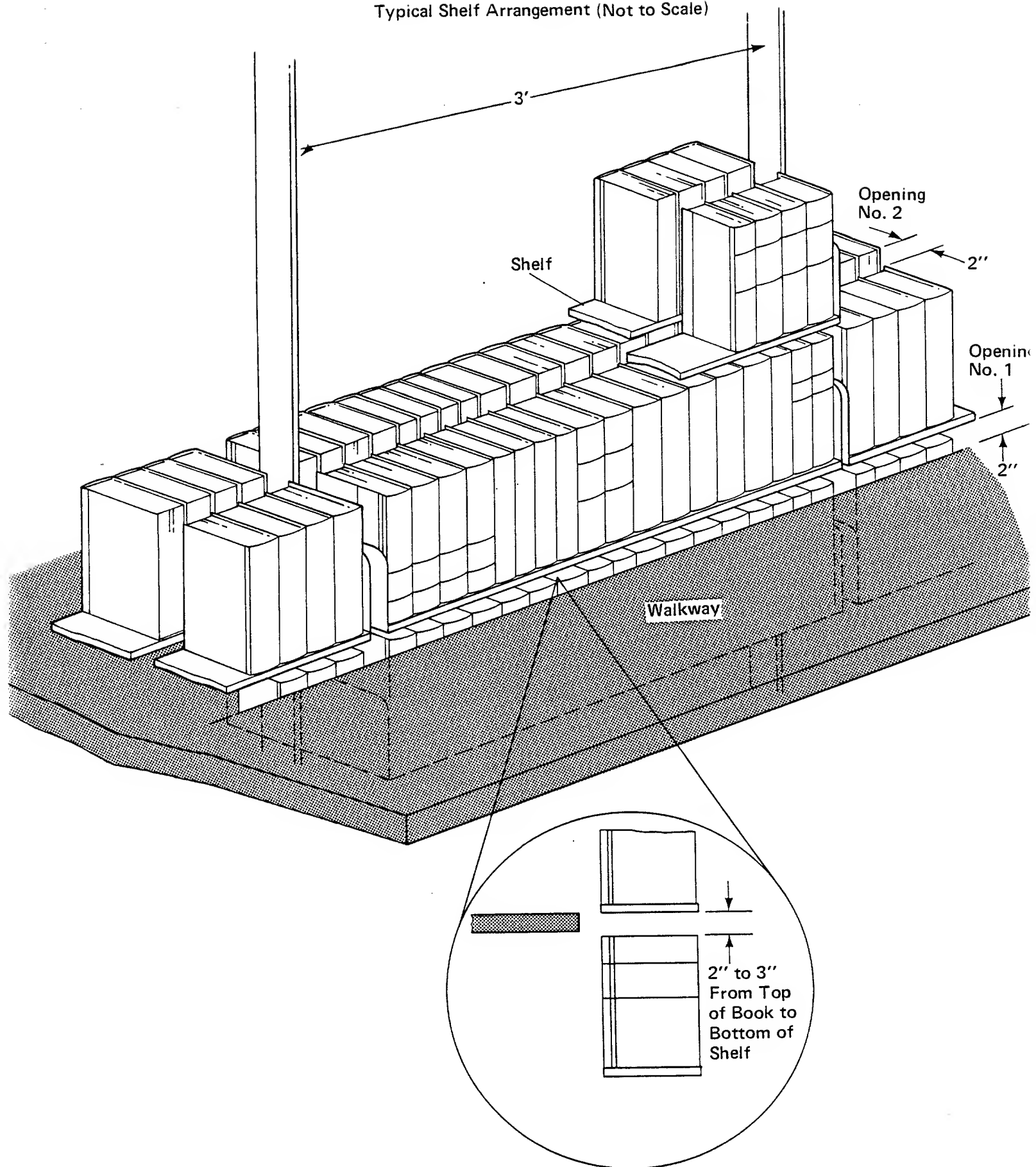


Figure 3

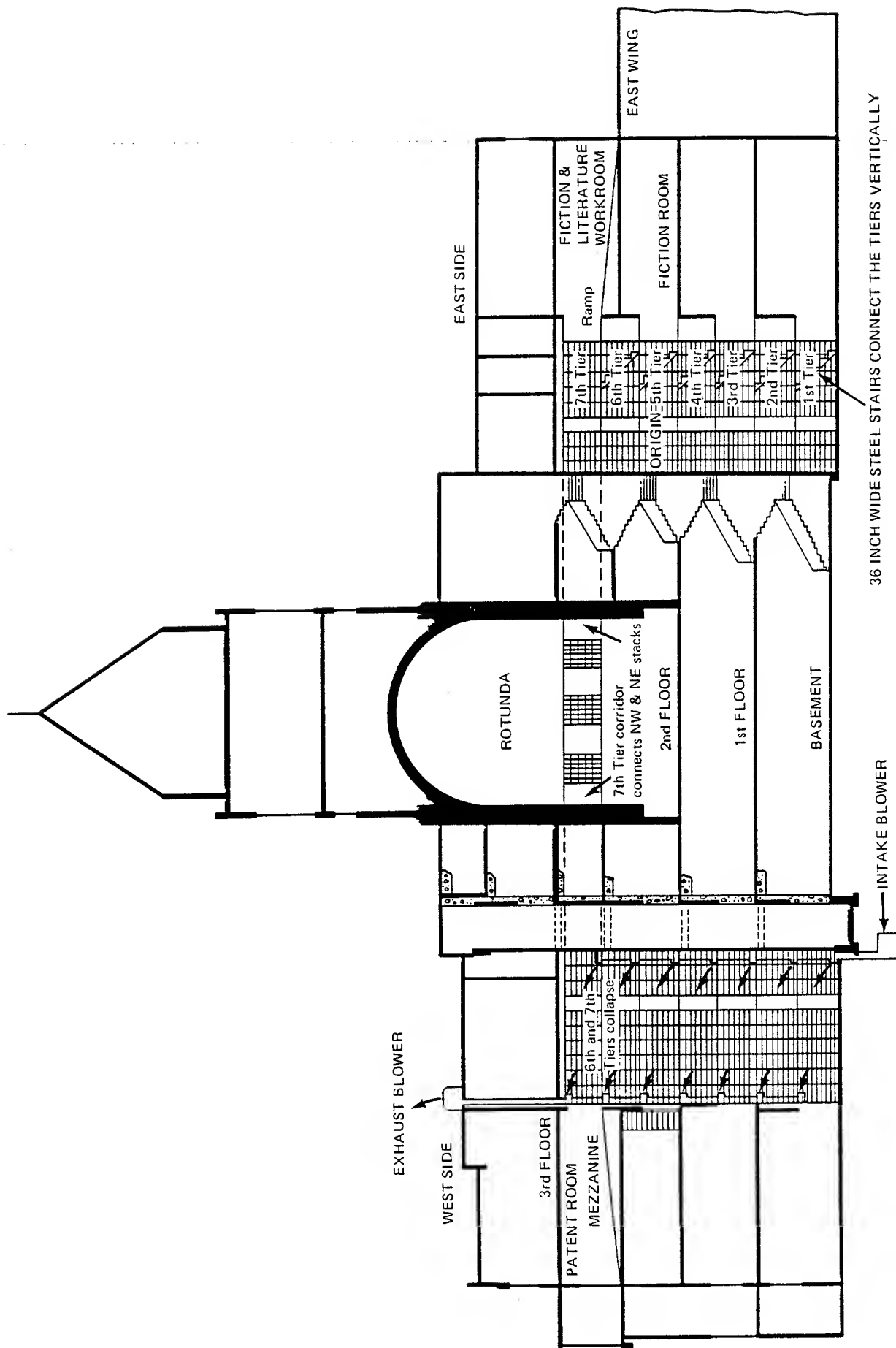


Figure 4

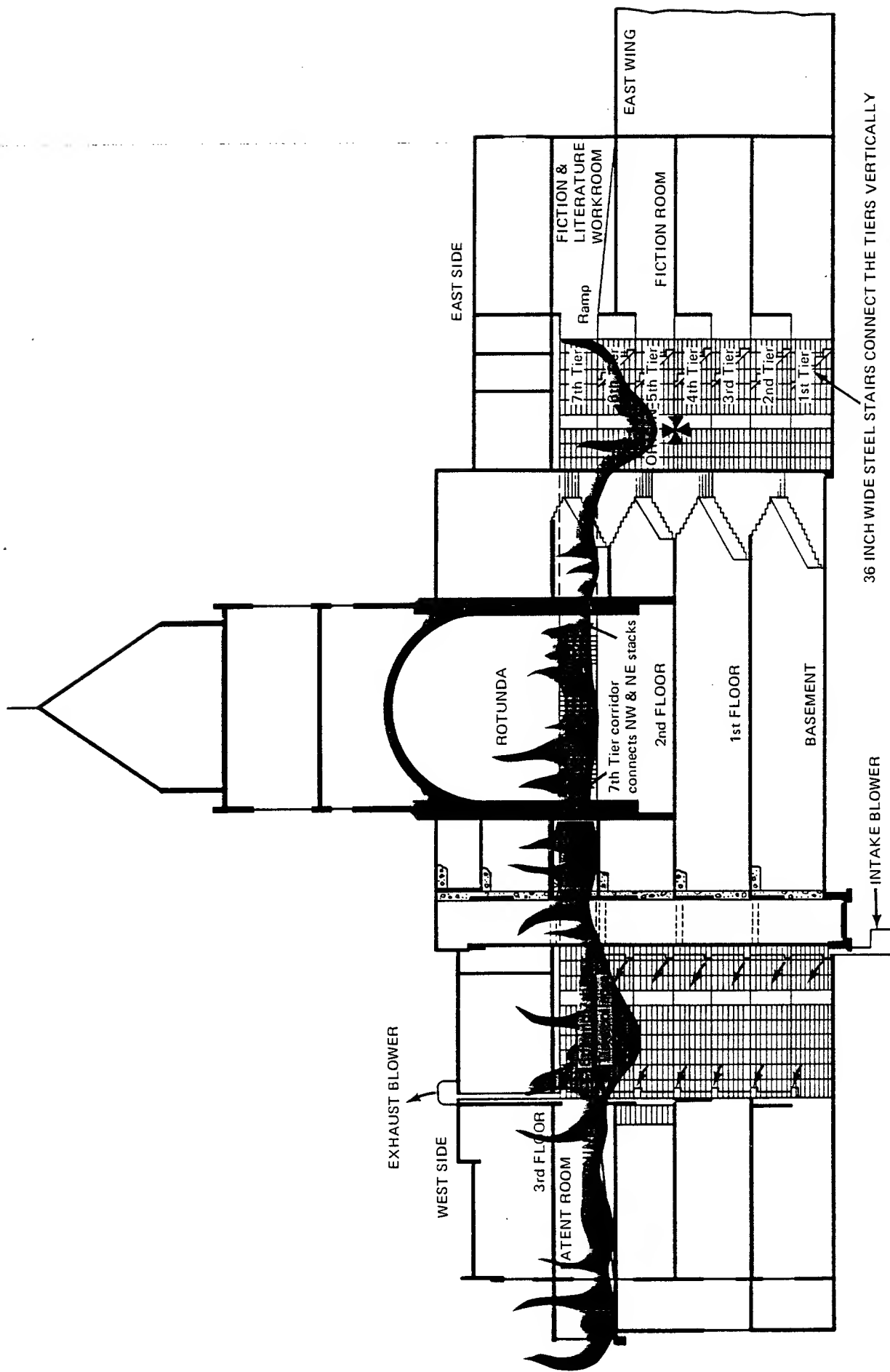
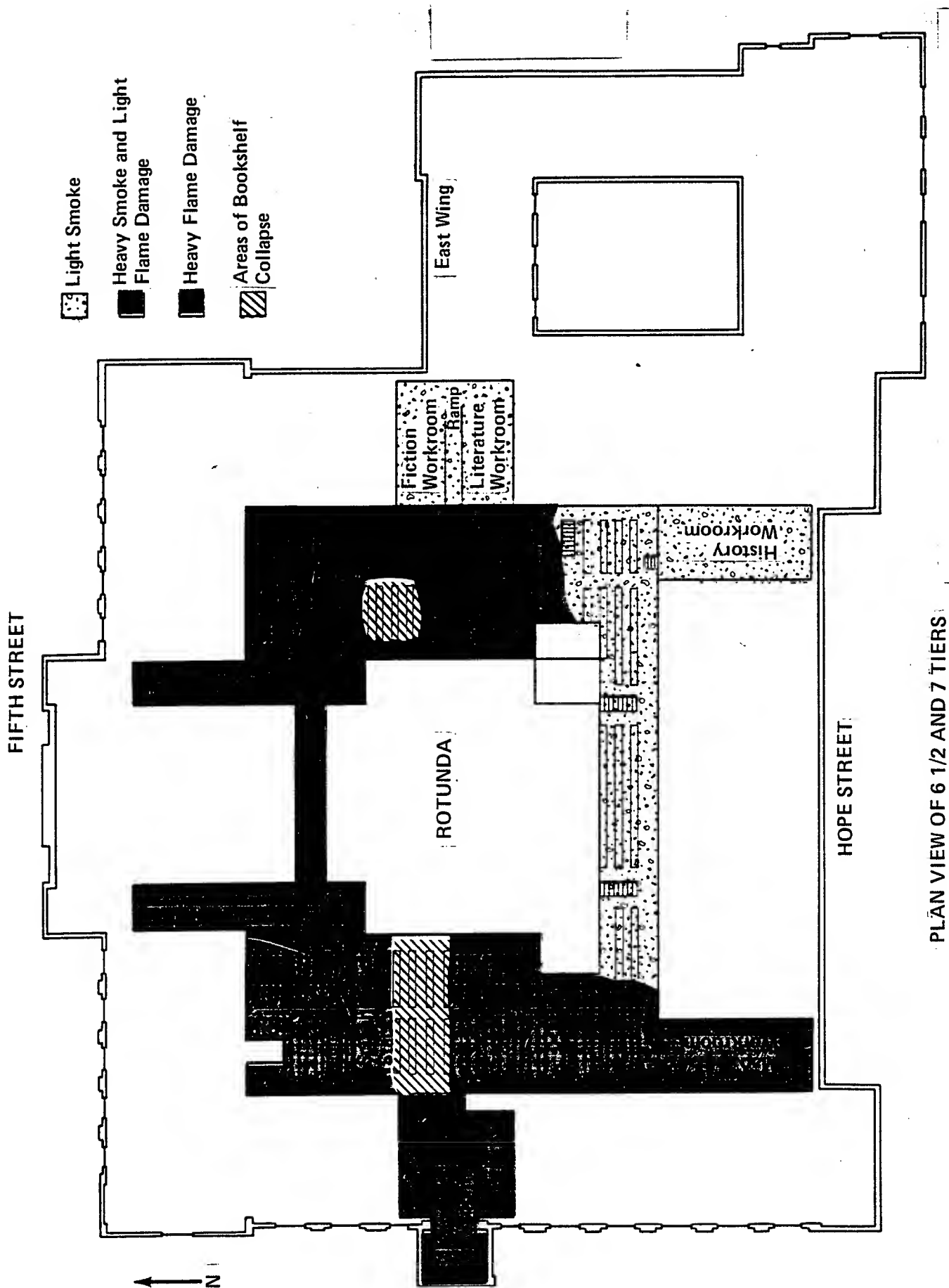


Figure 5



PLAN VIEW OF 6 1/2 AND 7 TIERS

Figure 6

Typical Shelf Arrangement (Not to Scale)

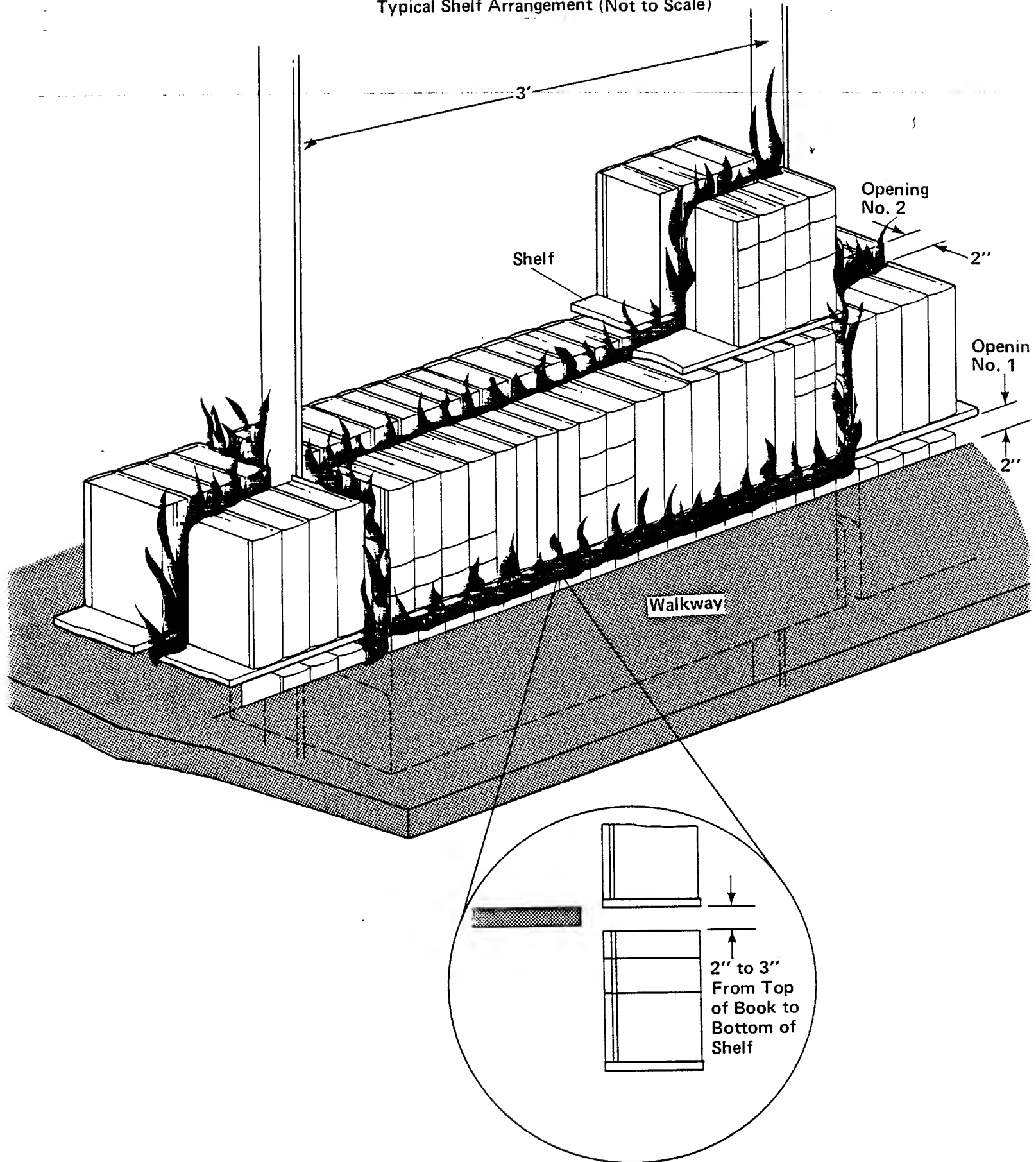


Figure 7

APPENDIX E
PHOTOGRAPHS

Photo 1
View Showing Northeast Corner and
East Wing of Library. Credit: John Morris



Photo 2
Framework which Supports Walkways and
Bookshelves in Stack Area. Credit: NFPA



Photo 3
Hope Street - South Side of Library. Pallet loads
of books that have been boxed and removed by Volunteers.
Credit: NFPA



Photo 4
Collapse Area, Northwest Stack, 7th Tier. Credit: NFPA



Photo 5
Patent Room, 6 1/2 Tier. Credit: NFPA



Photo 6
One Ventilation Hole as Viewed from the
3rd Floor Corridor. Credit: NFPA



Photo 7
One Ventilation Hole as Viewed from
The 7th Tier. Credit: NFPA